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GROWTH PARAMETERS RELATED TO PRODUCTIVITY IN CASSAVA (Manihot esculenta Crantz)

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GROWTH PARAMETERS RELATED TO PRODUCTIVITY IN CASSAVA (*Manihot esculenta* Crantz)

by

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APPROVAL SHEET

This thesis attached hereto, entitled "Growth parameters related to productivity in cassava (Manihot esculenta Crantz)" prepared and submitted by Tan Swee Lian in partial fulfilment of the requirements for the degree of Master of Agricultural Science, is hereby accepted.

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ABSTRACT

Dry matter production and distribution to major plant organs were studied by periodic harvests over 12 months in six varieties of cassava with varying branching patterns. Simultaneous studies traced the pattern of branching, leaf size and leaf area development, rates of leaf production and of node weight increase, and leaf life.

Total dry matter production depends on leaf area index (LAI) and leaf photosynthetic rate. Measurements by an infra-red gas analyzer on single attached leaves indicated varietal differences in apparent photosynthetic rates. The LAI of three varieties, with high, intermediate and low rates, was altered by leaf and apex clipping. A relationship was found between crop growth rate (CGR) and LAI, and a possible association between CGR and photosynthetic efficiency.

LAI is influenced by canopy characteristics, viz. leaf size, rate of leaf production and leaf life. Leaf production has two components: production rate per apex, and rate of apex production which relates to branching.

Root bulking has a lower optimal LAI than CGR, implying competition with dry matter utilization by stems, leaves and stakes. The capacity for branching determines LAI but also establishes the potential for top growth and its competitive sink strength. Node weight increased throughout the crop duration, and branching both augmented the stem mass and accelerated leaf production rate through rapid apex increase. Results from leaf and apex clipping suggest that new leaves constituted a very

substantial sink.

The simulation of branching patterns by pruning a highly branched variety showed that where the rate of apex number increase was moderate, root yields were high and similar to varieties with such characteristic branching patterns. Leaf life is important in maintaining LAI by precluding the need for rapid leaf production to replace abscised leaves. Introduced shade reduced leaf life, whilst highly branched varieties also had shorter leaf lives.

Optimal LAI for high root yield, therefore, may possibly be achieved through the selection of favourably branched phenotypes having long leaf life and superior photosynthetic capacity.

CHAPTER I

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is a crop of the New World, believed to have originated in the marginal zone between the tropical rain forests and savannahs in the area covered by Venezuela, north-eastern Brazil and Paraguay (de Candolle, 1886; Vavilov, 1951; Sauer, 1952; Smith, 1968). Rogers (1965) considered present-day southern Mexico, Guatemala and Honduras a likely secondary centre of origin. Its domestication has been attributed to the Arauk Indians, who were credited to have disseminated its cultivation as a result of their migrations to various parts of South and Central America (Schmidt, 1951; Rogers, 1965). Archaeological evidence seems to suggest that cassava has been in cultivation in Peru since 2000 B.C. (Sauer, 1951; Leon, 1977), rivalling maize (*Zea mays* L.) in antiquity (Smith, 1968).

Following their conquest of Brazil, the Portuguese introduced cassava into their colonies in Africa in the 16th century, and more recently into Asia, particularly India and South-East Asia in the 18th or 19th century (Purseglove, 1968; Montaldo, 1972a; Rogers & Appan, 1972; Nestel & Cock, 1976). Today, it has become the primary staple in many parts of Africa (Terry & MacIntyre, 1976), and an important source of carbohydrate in South America, with Brazil leading in production (Nestel & Cock, 1976).

The efficiency of cassava as a starch producer can hardly be questioned (de Vries *et al*., 1967; Kay, 1973; Cock, 1974). Starch, mainly in the form of amylose and amylopectin (Johnson & Raymond, 1965), is stored in the thickened roots at levels up to 71 tons/ha/year which is equivalent to 250 x 10^3 cal/ha/day in terms of energy (de Vries et al., 1967) (see Table I). The one-time research priority for the improvement of protein content in cassava roots (Bolhuis, 1953) has been acknowledged to be of secondary importance (Phillips, 1974) since this deficiency may be met by post-harvest processes such as microbial fermentation (Brook et al., 1969; Seerley, 1972; Phillips, 1974; Nestel & Cock, 1976).

Being a carbohydrate and hence an energy source, cassava finds an important place in the human diet (Jones, 1959; Phillips, 1974; Terry & MacIntyre, 1976), as a component of animal feed (Phillips, 1974; Nestel & MacIntyre, 1975; Terry & MacIntyre, 1976), and in various industrial processes based on starch - industries producing confectionery, foodstuffs, textiles, paper, alcohol, glucose and acetone (Normanha & Pereira, 1964; Kay, 1973; Araullo et al., 1974), to name a few. Table II gives a general picture of the main areas of cassava production and production figures (FAO, 1975).

Traditionally, cassava has been grown and tended by small farmers, and seldom, until recently, has it been managed in large commercial plantings. Perhaps, for this reason, there has been a noticeable lack of organized research on the crop (Nestel & MacIntyre, 1973; Nestel & Cock, 1976; Kawano et al., 1978) as compared, for instance, to maize. The total volume of literature related to cassava research up to 1972 was estimated by CIAT's documentation centre for cassava to be not more than 4000. However, of late, there has been an increasing interest in this long-

TABLE 1. MAXIMAL RECORDED YIELDS OF SOME IMPORTANT TROPICAL CROPS (After de Vries *et al*., 1967)

Crop	Yield (tons per ha per year)	Energy production (Cal/(ha.day) x 10^3)
Rice	26.0	176
Wheat	11.7	110
Maize	20.0	200
Sorghum	13.0	114
Cassava	71.1	250
Sweet potato	65.2	180
Banana	39.0	80

TABLE II. WORLD PRODUCTION OF CASSAVA (1975)
(Adapted from FAO Production Yearbook, 1975)

	Million tons		% world production	
Africa	43.97		41.79	
Nigeria		10.00		9.50
Zaire		9.17		8.72
Burundi		4.10		3.90
Tanzania		3.56		3.38
Mozambique		2.30		2.19
Ghana		1.80		1.71
Angola		1.60		1.52
Madagascar		1.42		1.35
Sudan		1.13		1.07
Central African Republic		1.10		1.05
Uganda		1.00		0.95
Asia	28.81		27.38	
Indonesia		12.92		12.28
Thailand		6.36		6.05
India		6.33		6.02
Malaysia		0.35		0.33
South America	31.43		29.87	
Brazil		27.21		25.86
Colombia		1.32		1.25
Paraguay		1.13		1.07
Others	1.00		0.95	
TOTAL	105.21		100.00	

neglected crop. This is largely due to the growing demand for cheap carbohydrate sources in the animal feed industries which has resulted in considerable attention being given by various national and international research bodies (Nestel & MacIntyre, 1973; Phillips, 1974; Wholey & Cock, 1975; Nestel & Cock, 1976). In recent years, Thailand has become one of the world's leading exporters in cassava because of the available animal feed markets in the European Economic Community (Phillips, 1974).

In view of the increasing demand for animal proteins due to population growth, consumer preference and a higher standard of living (Devendra, 1977), the government of Malaysia recognizes the need to expand the domestic livestock and animal product industries in order to achieve a higher degree of self-sufficiency. Projections up to 1990 for the demand for beef, mutton, pork, poultry, eggs and dairy products are given in Table III. It may be seen that the largest required increases are in the supplies of pork, poultry and eggs. Corresponding increases in the volume of feedstuffs will, therefore, be required to produce these animal proteins. The traditional source of energy in compounded feeds for non-ruminants has been maize, all of which is imported to furnish our local feed mills. By 1990, the total requirements for maize would have more than doubled to be able to satisfy the needs of the livestock industries (Table IV).

The continued dependence on maize for feeding pigs and poultry has been questioned (Devendra, 1977), especially since the cultivation of maize is more critical in its requirements and its yield performance is relatively unstable (Syed Ali, 1977; Wong, 1978) compared to an

TABLE III. ESTIMATED TOTAL REQUIREMENTS FOR DOMESTIC CONSUMPTION OF ANIMAL PRODUCTS IN MALAYSIA FROM 1975 TO 1990*
(Adapted from Veterinary Division, 1974)

Animal product	Unit	Total requirements			
		1975	1980	1985	1990
Beef (buffalo & cattle)	10^6 kg	18.6	22.1	26.3	31.3
Mutton (goat & sheep)	10^6 kg	4.8	5.7	6.7	8.0
Pork (pig)	10^6 kg	61.5	73.8	88.6	106.4
Poultry meat (chicken)	10^6 kg	83.1	123.9	184.5	279.4
Eggs (chicken)	10^6	1727.4	2411.4	3366.3	4699.4
Dairy products	10^6 l	353.8	406.9	468.1	538.4

*Assumes a 2.7% population growth rate, a growth rate in real income per capita of 2.8%, and income elasticities of demand of 0.3, 0.3, 0.4, 2.0, 1.5 and 0.5 for beef, mutton, pork, poultry meat, eggs and milk, respectively.

The meats refer to dressed carcasses, and were derived by applying a dressing percentage of 50 for cattle and buffalo, 50 for goat, 45 for sheep and 70 for chicken (approximately 230 kg liveweight/cow, 364 kg/buffalo, 18.2 kg/goat or sheep and 2 kg/chicken).

TABLE IV. THE REQUIREMENTS FOR ENERGY (MAIZE) AND THE TOTAL COST FOR SUPPORTING THE PRODUCTION OF MEAT AND MILK FROM THE LIVESTOCK CATEGORIES IN MALAYSIA (10^3 TONNES)

Animal Product	1975	1980	1985	1990
Pork (pigs)*	66.4	79.7	95.7	114.9
Broiler (chicken)**	74.8	111.5	166.1	247.4
Eggs (chicken)***	51.8	72.3	101.0	141.0
Milk (cows)+	22.2	25.5	28.7	33.7
Total requirements	215.2	289.0	391.5	537.0
Cost ($\$10^6$)++	94.7	127.2	172.3	236.3

* Based on an efficiency of feed conversion (EFC) of 3.6 feed units per unit liveweight gain, 30% maize in the diet.

** Based on an EFC of 3.0 feed units per unit liveweight gain, 30% maize in the diet.

*** Based on an EFC of 1.0 kg of feed/0.5 kg of egg mass, 30% maize in the diet.

+ Based on an average yield of 8 kg of milk/cow consuming 0.5 kg maize per day.

++ Costed at 44 cents/kg.

alternative energy source such as cassava. Animal nutrition studies have shown the feasibility of substituting a large portion of the maize component of feeds with cassava (Seerly, 1972; Muller et al., 1974; Hew, 1975; Syed Ali et al., 1975). The high-protein leaves of cassava (20.6 to 36.4%) render them potentially useful as a fodder crop, possibly replacing alfalfa in milk production (Murillo, 1952; de Guzman, 1978) because of its price advantage (Syed Jalaludin, 1977).

Malaysia is therefore endeavouring to expand her production of cassava to match the growing needs of her local feed mills. This necessitates equal if not greater efforts in research to ameliorate the production systems of the crop. Coursey & Haynes (1970) have pointed out that the genetic and agronomic potential of most root crops is still relatively unexplored. A better understanding of the crop's physiology is one of the necessary initial steps towards its fuller exploitation.

There is a dearth of information on the physiological aspect of productivity in cassava, as a literature review on the topic will reveal. Productivity encompasses both root yield and whole plant productive capacity. This latter is becoming of relevance since the leaves of cassava have been found to be suitable for use as forage.

It is mainly with this deficiency in knowledge in mind that the present studies were initiated. Without doubt, such information would be of interest and help to both the plant breeder and the agronomist in cassava research -- the former will then possibly attempt the improvement of morpho-physiological traits identified to be of importance to productivity and yield by means of genetics or the inherent qualities of the cultivars, whilst the latter will manipulate environmental and cultural factors to optimize, if not maximize, the performance of whichever of these traits already existing in his cultivars.

It was decided to adopt the growth analysis approach as the focal point of the present studies because this offers a means of observing the interaction of several traits selected for study during the various developmental phases of the crop, and their relative importance may possibly be recognized at each phase. Of course, a growth analysis provides, in addition, a general picture of the growth pattern and development of the crop.

There is surprisingly little research on the efficiency of the leaf surface, or the relative photosynthetic capacities of different cassava cultivars (Alagianagalingam & Ramakrishnan, 1970; Hunt, 1975b). An attempt is made here to look for varietal variation in net photosynthetic rates, and to relate these rates as measured in the laboratory under controlled conditions to crop performance in the field.

With a better understanding of the crop physiology of cassava, it might be possible to construct the "ideal" plant type with the optimal combination of desirable physiological characteristics which promise a high level of total productivity, and, more important, superior yields.

CHAPTER II

LITERATURE REVIEW

2.1 PREAMBLE

Man has been dependent on his crops ever since he gave up his nomadic way of life and ceased to rely entirely on hunting and foraging for his survival (Harlan, 1975). A settled form of life requires the assurance of a reliable food source. This has been achieved, short of natural calamities and disasters, through the domestication and cultivation or husbandry of plants and animals.

Through the ages, man has learnt through experience to select what appears to him to be the best (usually in terms of size, weight and/or appearance) for use as "seed material" in the following planting season. By this means, he has gained some degree of yield and quality improvement in the crops he grows. However, until about half a century ago, he failed to truly understand the underlying physiological processes and genetic factors which governed yielding capacity in his crops (Thurling, 1974). Research emphasis has, in the past, been on physiology at the molecular, cellular, or, at the very most, the plant level. These findings have without doubt helped in supplying the basic knowledge on physiological processes, but such results do not always give a clear picture of the behaviour of a crop stand which involves interaction between the plants as well as with the environment in which they are raised (Watson, 1952).

Crop physiology is the study of growth and development of a community of plants in relation to the different aspects of its environment. With the shift from research conducted under controlled or laboratory conditions to actual field situations, different techniques for study to be developed -- one of the most important being the growth analysis technique.

2.2 THE DEVELOPMENT OF THE GROWTH ANALYSIS TECHNIQUE

As growth is a continuous, highly intricate and ever-changing process, its study has to involve a time component. Growth analysis encompasses the study of metrical traits measured at regular time intervals throughout the life cycle of the plant with the aim of attempting to quantify growth. Among the earliest workers who tried to analyze growth and yields were Balls and Holton in 1915 (Watson, 1952) in their studies on cotton. They took daily measurements on plant height, rate of flowering and weekly counts of ripe bolls throughout the latter phase of the growth cycle in trying to relate yield with environmental variations in spacing, planting date, water supply, climate and pest infestations.

The formal concept of growth analysis was, however, developed by Blackman in 1919. He defined growth as a process obeying the "compound interest law", an idea conceived by Noll in 1906 (Evans, 1972). In other words, the rate of dry weight changes in plants at various time intervals was influenced by the existing amount of